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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H05K 7/20, H02B 1/56

A1

(11) International Publication Number: WO 00/62590

(43) International Publication Date: 19 October 2000 (19.10.00)

(21) International Application Number: PCT/IL00/00199

(22) International Filing Date: 30 March 2000 (30.03.00)

(30) Priority Data:
129392 11 April 1999 (11.04.99) IL

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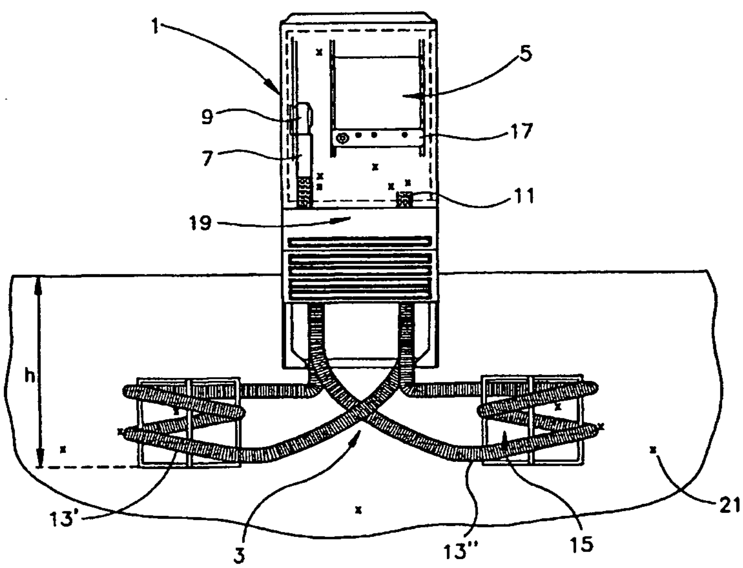
(81) Designated States: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: SYSTEM AND METHOD FOR HEAT EXCHANGING



(57) Abstract

A heat exchanging system for an outdoors electronic enclosure such as a street cabinet which comprises fluid ducting means, e.g. spirally coiled pipes. The fluid ducting means are adapted to surround a mass of soil acting as a solid phase thermal capacitor.

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SYSTEM AND METHOD FOR HEAT EXCHANGING

Field of Invention

The present invention relates to heat exchanging system, and in particularly to a system that is useful in cooling/heating outdoor electronic enclosures.

Background of the Invention

Outdoor systems comprising electronic components are commonly used in commercial and military applications all over the world. Such systems are used for ground support, countermeasures, communications, and many other applications. These systems must be capable of reliable operations for extended periods of time, preferably with no or little maintenance. For this reason fans and blowers were often discouraged in the past, and natural cooling was preferred, provided that natural convection cooling could effectively be used.

Another type of a problem associated with the cooling of electronic systems is the transient nature of the heating conditions e.g. in cases that power is turned on, when there is change in power, etc. Furthermore, outdoor systems are also exposed to transient heating conditions due to incident solar radiation. As the heat input to the system from this source is dependent upon the time of the day and the day of the year, thus the overall heat to be removed from the system may vary considerably. In various systems, the solar heat load may be at least as high as the total heat to be removed from all electronic components operating therein.

In the recent years, power dissipation and spatial heat density continued to increase in the electronic systems. This fact has a large impact upon the reliability of the electronic equipment as standard cooling methods could not provide adequate answers anymore. Consequently, various exotic solutions were suggested. One such solution was the use of a heat pipe. However, the biggest problem associated with this solutions is that heat pipes often exhibit degraded performance after they have been in operation for a short period of about 3 to 6 months. A degraded performance would result in increase of the equipment operating temperatures over a relatively short period of time, which leads to the occurrence of malfunctions and failures.

Another type of solution suggested in the art was liquid cooling which is much more effective than air cooling. Both liquid and air cooling systems may basically be classified as direct or indirect systems. In a direct cooling system, the coolant is in direct contact with the electronic components, allowing the coolant to pick up the heat and carry it efficiently away. In an indirect cooling system, the coolant does not get into direct contact with the electronic components. Instead, heat is transferred from the hot components to some intermediate media and therefrom to the coolant. The intermediate media conveys the heat to the coolant by conduction, convection or radiation. Typical examples of such indirect systems are heat exchangers and fans.

Direct liquid cooling systems usually have the electronic components completely immersed in a liquid, where the liquid should not have any effect upon the electrical operation of the system. Sometimes a pump is added to such a system to circulate the liquid through the electronics, increasing the cooling effectiveness. The major drawback of this method is that the electric components should be designed so that their performance will not be affected by their immersion in the liquid.

Indirect liquid cooling systems typically shift the heat transfer problem from the site of the electronic components to a more remote location. Since the heat must be dumped somewhere, it is often convenient to pump the coolant liquid to a remote air-to-liquid heat exchanger. Fans can then be used to drive cooling air through the heat exchanger, achieving cooling of the fluid by heating up the air. The cooled liquid is pumped back to the electronics to pick up more heat, and the hot air is exhausted to the surrounding ambient.

Liquid cooling systems should be completely enclosed systems. Therefore, some provisions must also be made to accommodate the thermal expansion of the liquid as the temperature increases. Also, air must be removed from the coolant and cushion must be provided to reduce pressure surges in the system.

Still, the fact that the electronic components that are in contact with the liquid must be properly sealed, remains a big disadvantage of the method, and causes a substantial increase in the system overall costs.

Another solution suggested in the past was to maintain the temperature of electronic equipment in outdoor enclosures by drawing ambient air directly into these enclosures. Although this solution is rather an efficient one, still some of the problems associated with such a solution are:

1. introducing moisture into the enclosure, which in turn damages the electronic components contained therein;
2. introducing dust that may block air filters and air ducting means within the enclosure; and
3. introducing industrial contaminations and fog into the enclosures, resulting in damaging the electronic components.

Therefore, in order to increase the operating reliability of the electronic components while reducing the maintainability required for such a system, the use of sealed enclosures e.g. for telecommunication cabinets, was suggested in the past. However, in order to remove heat from such enclosures, active heat transfer equipment must be incorporated. The commonly used active heat transfer devices were air to air heat exchangers and air conditioners. Unfortunately, also this solution suffers from a number of drawbacks. Among these are: higher enclosure volume required, increase in energy consumption, high air flow that results in considerable acoustic noise, and reduced overall reliability of the system.

US 3,987,344 describes a solution by which plug-in modules are inserted on the device's chassis, where the housing of each one of these modules is constructed to provide sufficient mass to dissipate the heat developed by the electronic components.

Another type of solution is disclosed by US 4,879,632, wherein a cooling module is provided with a heat transfer plate which is exposed to a coolant flowing for removing the heat dissipated at a printed circuit board.

US 5,258,888 discloses a natural convection cooled electronic device utilizing a box-like enclosure surrounding the circuitry of the electronic device. The device described in this publication further includes finned heat sinks arranged in a way so as to increase heat transfer rate from the device by utilizing conduction and radiation mechanisms.

An air conditioner that is tailored for cooing electronic enclosures is disclosed in US 5,036,677. The air conditioner described in this publication, comprises a specially designed cabinet containing a compressor, evaporator, condenser, a load air blower, an ambient air blower and a motor connected to these two blowers. This new design allows a reduction in the physical size of the cabinet while retaining the required cooling capacity.

Ambient air is the typical heat sink for the heat removed from electronic enclosures. However, another type of heat sink was investigated in a number of

research works for different applications, namely, the ground. Among these applications were heat storage for domestic use, e,g,. use of heat pump, heat dissipation from underground cables, disposal of waste heat from power plants, etc. The various researches that were carried out, concerned mostly using large volumes of ground with relatively small temperature differences, and were basically directed to solve steady state problems. One such example in the art is Mukerji S. et al. in J. of Thermophysics and Heat Transfer, Vol. 11, 2, pp. 182 – 188 (1997), who investigated several geometries of buried pipes heat exchangers.

Y. Rabin and E. Korin in "Thermal Analysis of Helical Heat Exchanger for Ground Thermal Energy Storage in Arid Zones", Int J. Heat Mass Transfer, vol. 39, No. 5 pp. 1051-1065 (1996) investigated the use of the ground for energy storage purposes. Their work describes the performance of the soil as an adequate storage means to which energy is being charged, and the system investigated was one with a time constant of about 30 days.

Ground coupled heat pumps as known in the art suffer from a major disadvantage that they have relatively low efficiencies and that they are inadequate to handle relatively rapid and substantial changes in the heat load.

Summary of the Invention

It is therefore an object of the present invention to provide a new and improved heat exchanging system.

It is another object of the present invention to provide a system for cooling or heating electrical/electronic enclosures, and improved methods of using such systems.

Other objects and advantages of the invention will become apparent from the description and claims that follow taken together with the appended drawings.

In accordance with the present invention there is provided a heat exchanging system for an outdoor electronic enclosure, having a fluid conveying means for conveying a heat transfer fluid which comprises:

(i) ingress means adapted to receive the heat transfer fluid flowing from at least one electronic enclosure;

(ii) delivery means for circulating the heat transfer fluid;

(iii) egress means for emitting the heat transfer fluid into the at least one

enclosure; and

(iv) fluid ducting means for transmitting the heat transfer fluid therethrough, connecting the ingress means to the egress means,

characterized in that the fluid ducting means is adapted to substantially surround a mass of a solid phase thermal capacitor.

The term "outdoor electronic enclosure" as used herein, is used to denote an enclosure that includes electronic components and/or electronic devices within that enclosure and is adapted to be positioned exposed at least partially to incident solar radiation.

The heat exchanging system of the present invention, may preferably be used for providing and/or removing heat from an outdoor located telecommunication cabinet, being the at least one enclosure.

According to a preferred embodiment of the present invention, the external and/or internal surface of the fluid ducting means, and more preferably their part adapted to substantially surround the mass of solid phase thermal capacitor, is provided with extended surface. Still more preferably, the fluid ducting means of the present invention is made of corrugated steel pipes.

In accordance with yet another aspect of the present invention there is provided a heat exchanging system for use in removing hat from or providing heat to at least one outdoor electronic enclosure, comprising:

(a) a fluid conveying means for conveying a heat transfer fluid comprising:

  (i) ingress means for receiving the heat transfer fluid from the at least one enclosure;

  (ii) delivery means for circulating the heat transfer fluid;

  (iii) egress means for emitting the heat transfer fluid into the at least one enclosure;

  (iv) fluid ducting means for transmitting the heat transfer fluid therethrough, connecting the ingress means to the egress means, and

(b) a solid phase thermal capacitor,

wherein the fluid ducting means substantially surrounds the solid phase thermal capacitor.

According to a preferred embodiment of the invention, the density of the solid phase thermal capacitor is in the range of from about 1300 to about 2200 kg/m^3. The heat capacity of the phase thermal capacitor is preferably in the range of from about 500 J/(Kg-°C) to about 2500 J/(Kg-°C). Examples of materials that are suitable to be used as such thermal capacitors are soil, concrete, mixtures comprising sand and gravel, and the like

In case that the solid phase thermal capacitor is soil, the fluid ducting means of the heat exchanging system of present invention should preferably be buried deeper than the ground surface level. The reason being that a preferred solid phase thermal capacitor should have a substantially constant temperature (say within about ±5°C), independent of the time of the day and the day of the year. For most types of soils this may typically be satisfied at a depth exceeding 30 cm from ground surface. Obviously, as may be appreciated by a person skilled in the art, although this minimum depth value characterizes a large number of soil types, still it may vary depending upon the type of soil. Thus, the present invention should not be considered to be bounded by the value set above. More preferably, for most types of soils where soil is the solid phase thermal capacitor, the major portion of the exchange of heat takes place at a depth of from about 50 cm to about 150 cm from ground surface.

According to yet another preferred embodiment of the invention, the mass substantially surrounded by the ducting means comprises a conducting agent (referred to hereinafter as "CA") which is adapted to increase the rate by which heat id conducted from or to the fluid ducting means. By this embodiment, heat is transferred to (or from) the CA, and therefrom to the soil being the solid phase thermal capacitor. Preferred CAs according to the present invention are CAs that possess stable physical characteristics such as materials characterized with heat conduction coefficients that would not decrease with time. Examples of such possible CAs are mixtures of sea sand (having high quartz content) and crushed gravel or crushed granite. Typically, such a mixture will have an average particle size of 1.5 – 2.5 mm and will comprise 30 to 50% by weight of crushed gravel/granite of the overall mixture weight.

Similarly, the heat exchanging system of the present invention could be used in cold climate countries, allowing the drawing of heat from the ground for heating the enclosure or specific part(s) and/or components thereof.

According to still another preferred embodiment of the invention, the heat exchanging system is further provided with a controller to control the operation of the heat exchanging system, e.g. by controlling the delivery means thereof. Such a controller can be used as an efficient way of matching the performance of the solid phase thermal capacitor with the overall heating/cooling requirements of the system. A simple yet effective method of carrying out such control is by using on/off controller for stopping the flow of the heat transfer fluid at certain periods, e.g. at night.

In accordance with still another aspect of the present invention there is provided a method for removing heat from at least one outdoor electronic enclosure to the ground comprising circulating a heat transfer fluid via a fluid conveying means which method comprises:

(i) providing ingress means for receiving the heat transfer fluid from the at least one outdoor enclosure;

(ii) circulating the heat transfer fluid;

(iii) providing egress means for emitting the heat transfer fluid into the at least one enclosure; and

(iv) transmitting the heat transfer fluid via fluid ducting means that are buried at least partially in the ground in a substantially spirally coiled shape surrounding a pre-defined mass of the ground.

Thus, the method provided allows the transfer of heat from the at least one outdoor electronic enclosure to the ground.

A similar method, *mutatis mutandis*, may be used to provide heat from the ground to at least one outdoor electronic enclosure.

Various types of fluids are suitablr for use as heat transfer fluids in the heat exchanging system of the present invention as explained before. By a preferred embodiment of the invention, the heat transfer fluid is air.

According to yet another aspect of the present invention, there is provided a method for installing a heat exchanging system for an outdoor telecommunication cabinet comprising:

(i) providing a fluid conveying means for conveying a heat transfer fluid which comprises:

(a) ingress means for receiving the heat transfer fluid from the outdoor telecommunication cabinet;

(b) delivery means for circulating the heat transfer fluid;

(c) egress means for emitting the heat transfer fluid into the outdoor telecommunication cabinet; and

(d) fluid ducting means for transmitting the heat transfer fluid therethrough, connecting the ingress means to the egress means;

(ii) installing the fluid ducting means so that they are buried at least partially in the ground in a substantially spirally coiled shape so as to surround a pre-defined mass of the ground;

Brief Description of the Drawings

Fig. 1 illustrates a system incorporating the heat exchanging system of the present invention;

Fig. 2 presents an electrical analogy of the system illustrated in Fig. 1;

Fig. 3 illustrates schematically a section of a corrugated pipe which, according to a preferred embodiment of the invention, may be used as the ducting means of the heat exchanging system;

Fig. 4 shows experimental profiles of the air temperature within the electronic system and of the ground temperature;

Fig. 5 presents various experimental temperature profiles of the set-up used;

Fig. 6 shows theoretical results of the heat loads that can be removed from the system as a function of the ducting means diameter;

Figs. 7a and 7b present the geometrical basis for simulating a heat exchanging system known in the prior art; and

Fig. 8 presents a comparison of the heat loads that can be removed from a system when using the heat exchanging system of the present invention, and that known from prior art.

Detailed Description of the Invention

The heat exchanging system of the present invention comprises the following: a fluid conveying means for conveying a heat transfer fluid including:

(i) ingress means for receiving the heat transfer fluid from an at least one outdoor electronic enclosure;

(ii) delivery means for circulating the heat transfer fluid;

(iii) egress means for emitting the hat transfer fluid into the at least one enclosure; and

(iv) fluid ducting means for transmitting the heat transfer fluid therethrough, connecting the ingress means to the egress means, and wherein the fluid ducting means is adapted to substantially circle a mass of a solid phase thermal capacitor.

As was previously explained, a volume of soil present in the vicinity of the enclosure to be thermally treated is used a preferred thermal capacitor according to the present invention. Such a soil volume is preferably chosen next to or underneath that enclosure. Fig. 1 presents schematically a non-limiting example of an outdoor telecommunication cabinet 1 and heat exchanging system of invention, 3, associated therewith. Cabinet 1 comprises an electronics compartment 5 that includes various electronic components, some or all of which are heat dissipating components. The removal of the heat load is carried out to ensure that a desired temperature threshold is not exceeded within the cabinet. The heat load of cabinet 1 originates from two main sources. The first source is heat dissipation due to the operation of the electronic components, and the second, incident solar radiation absorbed by the cabinet. Part of the overall heat load is removed to the ambient air, whereas the balance of the heat load is removed by using heat exchanging system 3 (to be referred to hereinafter as "HES"), to the ground. HES 3 comprises ingress means 7 used to draw heated air from the cabinet inner space, blower 9 for delivering the air which is the heat transfer fluid of this example, through the HES, ducting means 13' and 13" where the heat exchange from the air to the ground takes place, and egress means 11 through which the air is introduced back into the cabinet inner space. In this example, cabinet 1 further comprises a number of fans 17 used for circulating air within the cabinet inner space for reducing or preferably even preventing, formation of hot spots inside the cabinet. Also, cabinet 1 comprises an electric operating system 19 which may optionally comprise a control system operative to control the way when an how the HES is used. A typical mode of operation by which the above described system operates is as follows. Air in the cabinet inner space absorbs both the heat dissipated from the various electronic components e.g. PCBs, fans and the like, as well as the heat transferred inwardly from the cabinet inner envelope when the external envelope of the cabinet is heated by the incident solar radiation. Blower 9 delivers the heated air through intake 7 and towards the ducting means of the system. This flow of heated

air may be divided into a number of flows, as in the present example where it is divided into two or more parts, not necessarily two equal ones, and flows through a spirally coiled buried pipe (in our example 13' and 13", respectively). The ducting means of the example is illustrated as comprising two parallel parts. These two parts may either be operated together, or independently of each other, allowing also for a back-up if required. Each of these two spirally coiled pipes presented, is buried in a way so that it substantially circles a mass of soil 15 (referred to hereinafter as "MS") used as a thermal capacitor. Alternatively, the MS surrounded by one or both of these coiled pipes may further comprise, or be substantially comprised of, a conducting agent (CA). This CA is used for improving the heat transfer between the ground and the pipes buried. The coiled pipes shown, are placed at a depth h. In cases where h exceeds about 1 meter (measured from ground level), the soil temperature remains substantially constant and is relatively unaffected by rapid changes occurring in the ambient temperature.

Notwithstanding the above, it is also known that in cold countries, the ground temperature at certain depths may be higher than that of the ambient air. This fact enables to utilize the ground in such places as an energy source to provide heat into the enclosure.

Fig. 2 illustrates an electrical analogy of the system presented in Fig. 1. There are two sources for the heat to be removed from the cabinet. Q_1, is the heat dissipated from the electronic components located within the cabinet and is relatively constant, and Q_2, the solar radiation heat load which is a variable load depending on time of the day, day in the year, cloudiness etc. In this analogy, resistors present thermal resistance; voltage difference presents temperature difference; current sources present heat power sources and thermal capacitors – heat capacitors. R_1 shown in the Figure is the resistance existing between the cabinet inner envelope and the ambient. This resistance is comprised of resistance to conduction through the cabinet envelope and resistance associated with the three mechanisms of transferring heat to the ambient, namely conduction, convection and radiation. R_2 is the resistance existing between the electronic components dissipating heat and the cabinet envelope. R_3 is the resistance existing between the inner space of the cabinet and the MS, whereas R4 is the resistance between the MS and the far ground (which is practically unaffected by the operation of the system). C_1 is the capacitance of the MS being substantially circled by the spirally coiled buried pipe(s), and C_2 is the capacitance of

the far ground, which can in fact be regarded as an infinite capacitor. The temperatures associated with this analogy are: T – the time dependent temperature within the cabinet; T_a – ambient air temperature, and T_G – the far ground temperature.

According to another aspect of the present invention, the ducting means of the heat exchanging system, and in particular their part being in contact with the thermal capacitor or the CA, are provided with extended external surface, and preferably with extended surface on both their external and internal surfaces. One preferred example for this aspect of the invention is a corrugated pipe as illustrated in Fig. 3. Typical characterizing parameters of such a corrugated steel pipe in a system as described in Fig. 1 are: thickness, t, in the range of 0.2 to 0.4 mm; inner diameter, d, in the range of from about 40 mm to about 80 mm; outer diameter, D, in the range of from about 45 mm to about 100 mm, curvature, R, in the range of from about 2 mm to about 10 mm, and the distance between two consecutive peaks P, is in the range of from about 5 mm to about 15 mm.

Examples

The following non-limiting examples will be used to illustrate some aspects of the present invention.

Example 1

The system illustrated in Fig. 1 and described above was used in the following Example.

An outdoor telecommunication cabinet made of reinforced polyester was positioned in a way described above. Heaters dissipating a total of 400 W were placed in electronic compartment 5, simulating power dissipating from electronic components within the cabinet. The volume of the air filling the cabinet inner space was roughly equal to 0.35 m^3. Three fans, 19, consuming a total of 30 W, were used to circulate the air within that space. Still, temperature gradients of up to about 4-5°C were observed within the cabinet inner space. In the experiments, a number of temperatures were measured in various parts of the system as well as in its surroundings. These measurements were made by using thermistors 21 located in places as indicated in Fig. 1 by the notation x.

Two corrugated spirally coiled pipes made of steel, 13' and 13" were used as the air-ground heat exchangers in the experimental set-up. Each of these coiled pipes had an inner diameter of 2", and a 4.5 meters long buried part. MS's 15 that were circled each by one of the coiled pipes had approximately the dimensions: 60 X 60 X 40cm, per MS.

Fig. 4 presents various temperature profiles that were measured during a run that extended during a summer period for about 3 days (measured ambient temperature was up to 35°C). Curve *a* presents the cabinet inner-air temperature during the experiment, whereas curve *b* presents the corresponding MS ground temperature at a depth of about 80cm. The total heat load (including solar radiation) removed by the HES during the experiment was about 650 to 700 W. About 400 W of the overall heat were removed by the HES of the present invention, whereas the rest of the heat load was removed mainly by convection and radiation via the cabinet external envelope to the surrounding air. As may be seen from this Fig., the temperature of the air entering the HES is typically in the range of 42 to 52°C. It is also clear from the Figure that solar radiation does have a considerable effect on the air temperature. The cabinet air temperature sharply increases at times when solar radiation was absorbed by the cabinet, while the ground temperature remained relatively constant. Also, it may be seen in Fig. 4 that the air peak temperature and the MS peak temperature do not coincide, and there is a certain leg between the two, a leg that might be explained by the capacitance of the MS. A typical operation of the system also included the disconnection of the HES operation during nighttime. Thus, when the system was put into operation, a rapid effect is noticeable, decreasing the cabinet internal temperature by about 3-5°C.

Fig. 5 presents several temperature profiles measured at various elements of the experimental set-up. Curve *a* presents the air temperature measured at the HES inlet (the hot air); curve *b* present the air temperature measured at the HES outlet (the cooled air); curve *c* presents the MS temperature; curve *d* shows the temperature measured at a distance of 10 cm from a coil; curve *e* presents the far ground temperature which is practically constant, and curve *f* present the ambient air temperature.

Example 2

Based on the above experimental set-up, a computer model was constructed. The model was used to evaluate the effect of various parameters upon the system performance. One of these parameters was the diameter of the spirally coiled pipe. Fig. 6 presents the results obtained in flux [W/m^2] as a function of the diameter. To calculate the total heat removable from a pipe, the value of the flux as shown in the Fig. should be multiplied by the outer surface area of that pipe.

Example 3

In the present Example, a model comparison was made between the performance of an HES of the present invention, and of a conventional tube array type heat exchanging system. In both cases, the application was to remove heat from an outdoor telecommunication cabinet.

In addition to the model describing the HES of the present invention, another finite element model was constructed, incorporating the tube array heat exchanging system as presented in Figs. 7a and 7b. The parameters set for running the two models were the following:

Table 1 – Parameters used in comparing a coil heat exchanger with a tube array heat exchanger for cooling an outdoor telecommunication cabinet.

Parameter	Coil Heat Exchanger	Tube Array Heat Exchanger
Tube/coil diameter [mm]	50	50
Length of buried part [m]	9	9
Volume of CA [m^3]	0.49	0.54
MS volume [m^3]	0.16	0.17
CA conductivity range [w/m°C]	0.65 – 1.0	0.65 – 1.0
CA capacitance [J/Kg°C]	1000	1000
Far ground conductivity [w/m°C]	0.3 top layer (dry) 0.65 bottom layer	0.3 top layer (dry) 0.65 bottom layer
Far ground capacitance [J/Kg°C]	1000	1000
Far ground temp. range [°C]	27 – 32	27 – 32

Some of the results obtained are presented in Fig. 8, showing the power dissipated from a control volume which included the heat exchanger tested, the CA and the MS defined above. Curve *a* presents the load [W} removed while using the tube array hat exchanger and curve *b* – the load removed by the hat exchanger surrounding the MS.

The results may be summarized in the following way. The load removed while using a tube array heat exchanger is more uniform throughout a 24 hours period (including the simulation of a day and night conditions) than that removed while using the HES of the present invention, however, the integration of the total amount of heat removed during that 24 hours period indicated a relatively small advantage to the HES of the present invention over the tube array heat exchanger. Still. the most important difference found between the two types of heat exchangers was in the pick heat loads that could be removed. As previously explained, the present invention is directed to provide a solution to situations where the heat load may significantly be changed throughout the operation of the electronic devices located within the enclosure. In our case, these changes are due to the impact of the solar radiation upon the heat load to be removed. It can clearly be noted from Fig. 8 that the heat exchanger of the present invention provides a better solution for removing transient heat loads, when compared with the conventional type of heat exchanger.

It is to be understood that the above description and examples only include some embodiments of the invention and serve for its illustration. Numerous other ways of choosing heat exchangers may be devised by a person skilled in the art without departing from the scope of the invention, and are thus encompassed by the present invention. Rather, the scope of the present invention is defined by the claims that follow:

Claims:

1. A heat exchanging system for an outdoor electronic enclosure, having a fluid conveying means for conveying a heat transfer fluid comprising:
   (i) ingress means adapted to receive said heat transfer fluid flowing from at least one electronic enclosure;
   (ii) delivery means for circulating said heat transfer fluid;
   (iii) egress means for emitting said heat transfer fluid into the at least one enclosure; and
   (iv) fluid ducting means for transmitting said heat transfer fluid therethrough, connecting the ingress means to the egress means,

   characterized in that the fluid ducting means is adapted to substantially surround a mass of a solid phase thermal capacitor.
2. A heat exchanging system according to Claim 1, wherein said fluid ducting means comprises corrugated pipes.
3. A heat exchanging system according to Claim 1, wherein said fluid ducting means comprises spirally coiled pipes.
4. A heat exchanging system according to Claim 1, wherein said fluid ducting means are provided with at least one extended surface.
5. A heat exchanging system for use in removing heat from or providing heat to at least one outdoor electronic enclosure, comprising:

(a) a fluid conveying means for conveying a heat transfer fluid including:
   (i) ingress means for receiving said heat transfer fluid from said at least one outdoor electronic enclosure;
   (ii) delivery means for circulating said heat transfer fluid;
   (iii) egress means for emitting said heat transfer fluid into said at least one enclosure;
   (iv) fluid ducting means for transmitting said heat transfer fluid therethrough, connecting said ingress means, and a solid phase thermal capacitor,

(b) a solid ducting means substantially surrounds said solid phase thermal capacitor.

6. A heat exchanging system according to claim 5, wherein said solid phase thermal capacitor is soil.
7. A heat exchanging system according to Claim 5, wherein said fluid ducting means are buried in the ground at a depth at a least 30 cm from the ground surface.
8. A heat exchanging system according to Claim 7, wherein said fluid ducting means are buried in the ground at a depth of from about 50 cm to about 120 cm from the ground surface.
9. A heat exchanging system according Claim 5, wherein said fluid ducting means are substantially surrounded with a conducting agent.
10. A heat exchanging system according to Claim 9, wherein said conducting agent is a mixture comprising sea sand and crushed gravel.
11. A heat exchanging system according to Claim 9, wherein said conducting agent is a mixture comprising sea sand and crushed granite.
12. A heat exchanging system according to Claim 1, further comprising control means.
13. A heat exchanging system according to Claim 1, wherein said at least one outdoor enclosure is a telecommunication cabinet.
14. A method for removing heat from at least one outdoor electronic enclosure to the ground comprising circulating a heat transfer fluid via a fluid conveying means which method comprises:
    (i) providing ingress means for receiving the heat transfer fluid from the at least one outdoor enclosure;
    (ii) circulating the heat transfer fluid;
    (iii) providing egress means for emitting the heat transfer fluid into the at least one enclosure; and
    (iv) transmitting the heat transfer fluid via fluid ducting means that are buried at least partially in the ground in a substantially spirally coiled shape surrounding a pre-defined mass of the ground.
15. A method for installing a heat exchanging system for an outdoor telecommunication cabinet comprising:

(i) providing a fluid conveying means for conveying a heat transfer fluid including:

(a) ingress means for receiving said heat transfer fluid from said outdoor telecommunication cabinet;

(b) delivery means for circulating said heat transfer fluid;

(c) egress means for emitting said heat transfer fluid into said outdoor telecommunication cabinet; and

(d) fluid ducting means for transmitting said heat transfer fluid therethrough, connecting said ingress means to said egress means;

(ii) installing said fluid ducting means so that they are buried at least partially in the ground in a substantially spirally coiled shape so as to surround a pre-defined mass of the ground.

16. A heat exchanging system according to Claim 1, wherein said heat transfer fluid is air.

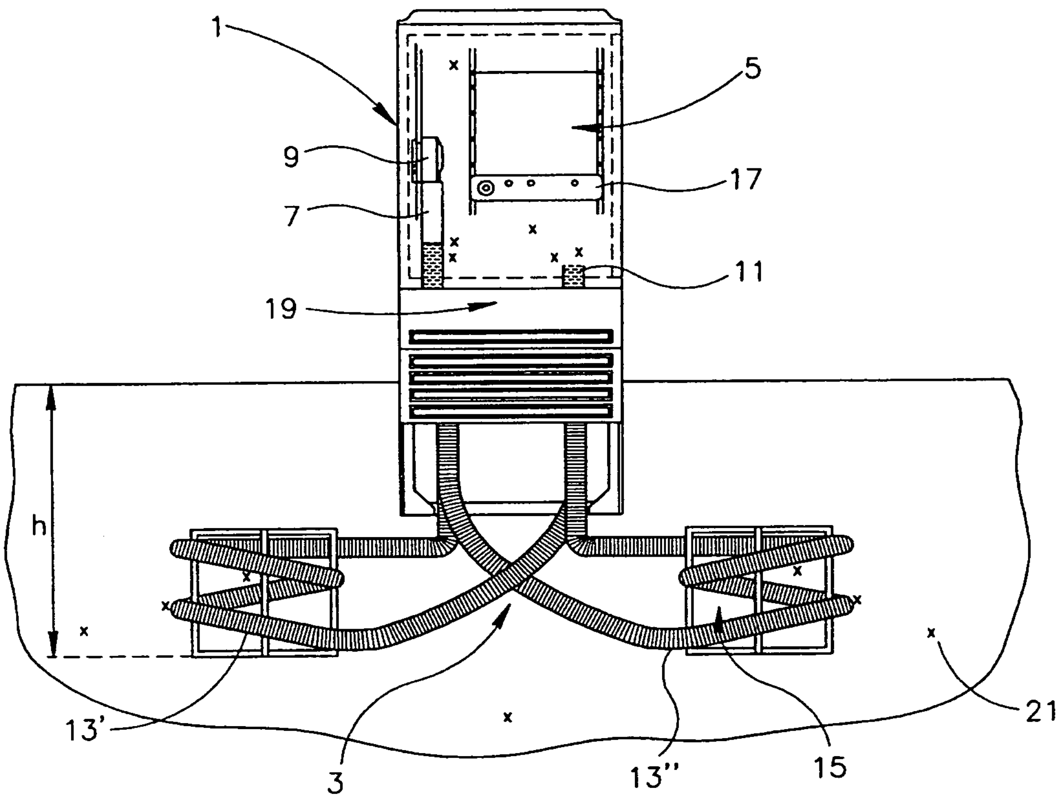


FIG.1

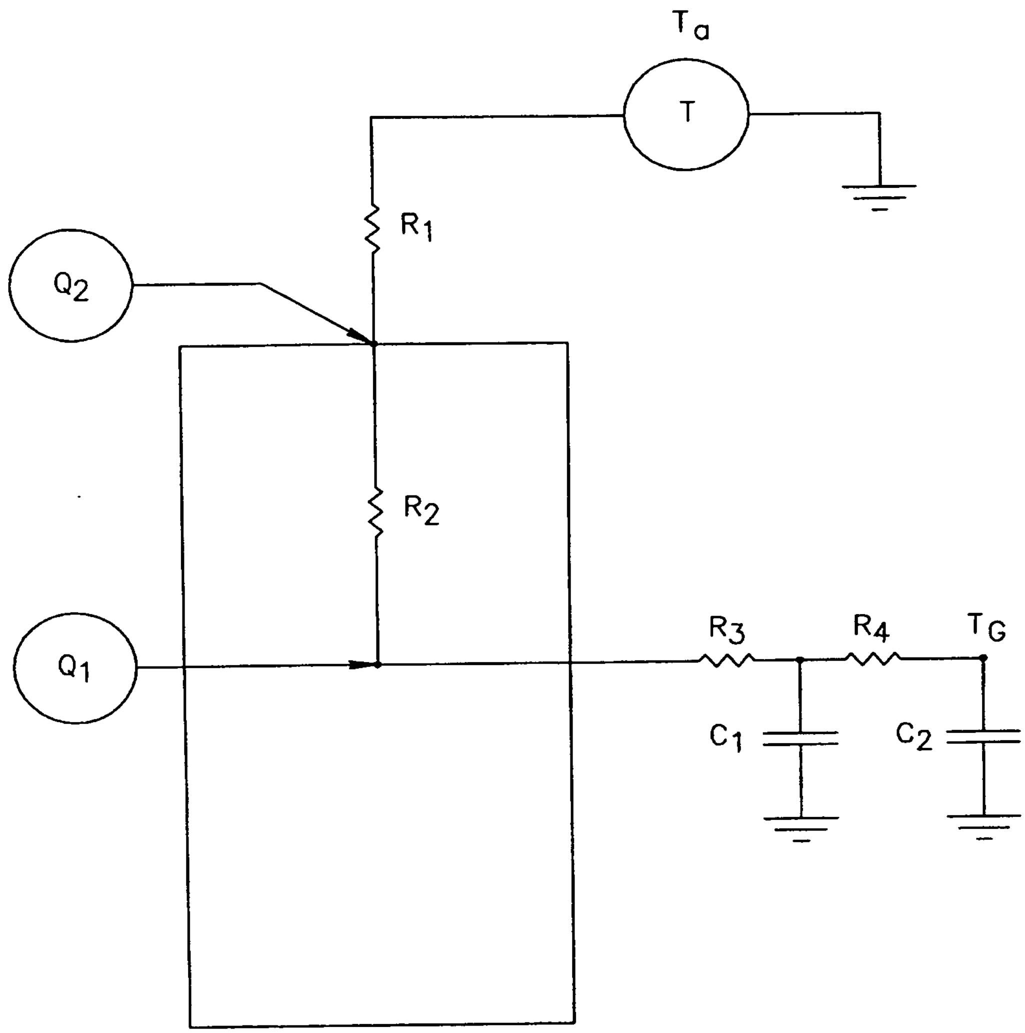


FIG.2

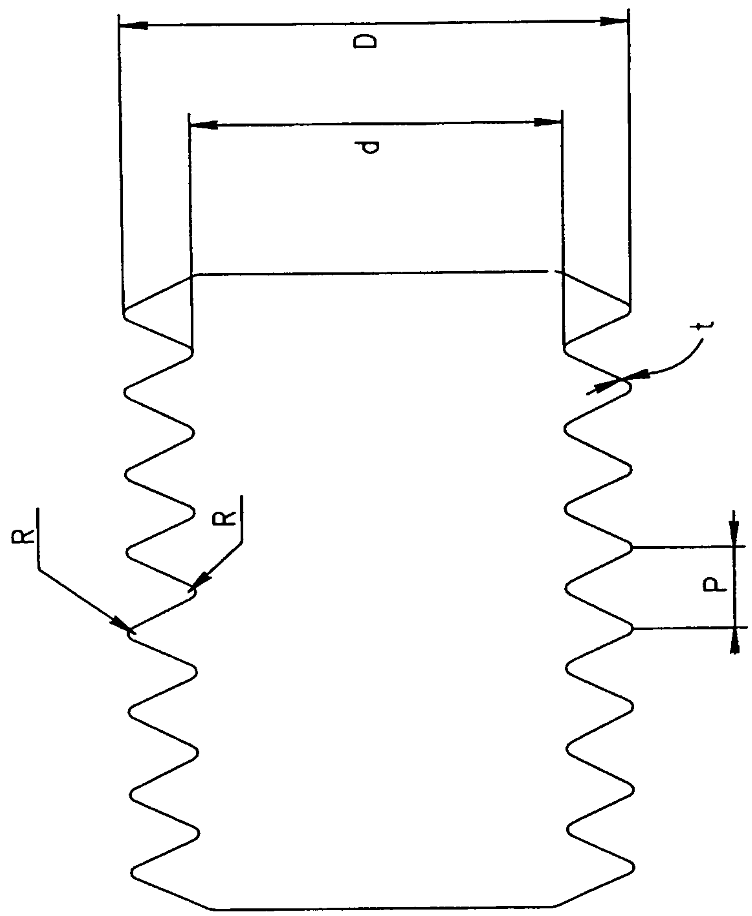
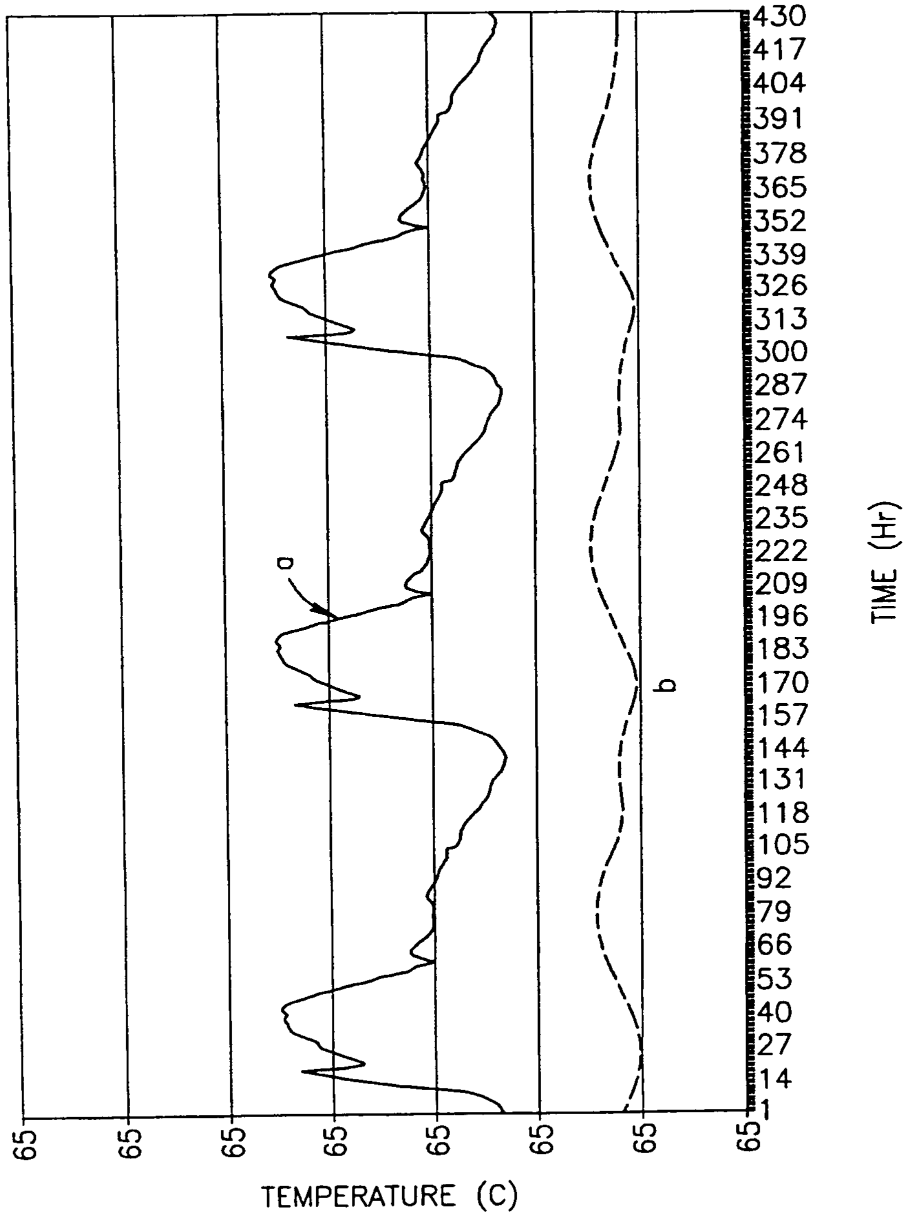


FIG.3


65
65
65
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65
65
65
65
65
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27
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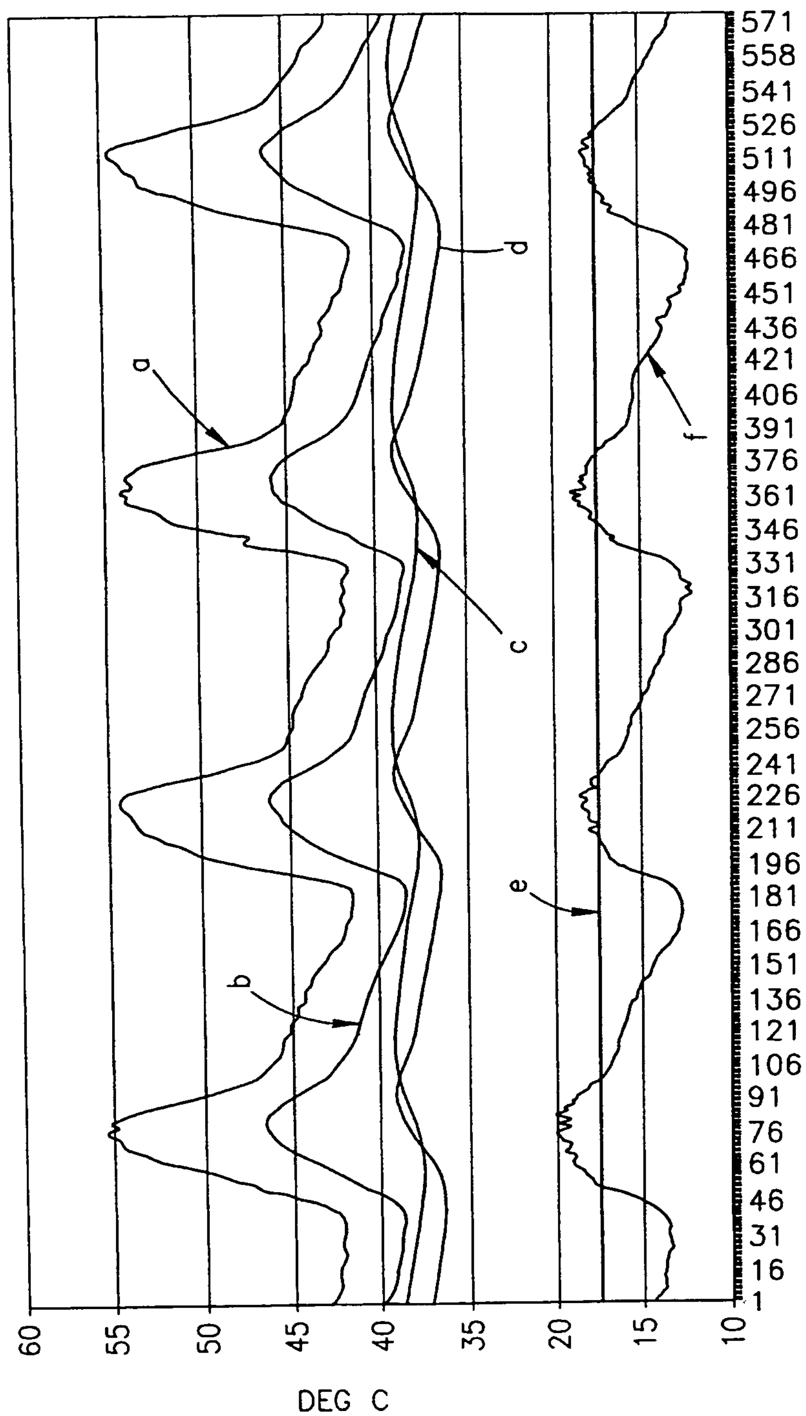
53
66
79
92
105
118
131
144
157
170
183
196
209
222
235
248
261
274
287
300
313
326
339
352
365
378
391
404
417
430
TIME (Hr)
a
b

FIG.4


DEG C
60
55
50
45
40
35
20
15
10
TIME
1
16
31
46
61
76
91
106
121
136
151
166
181
196
211
226
241
256
271
286
301
316
331
346
361
376
391
406
421
436
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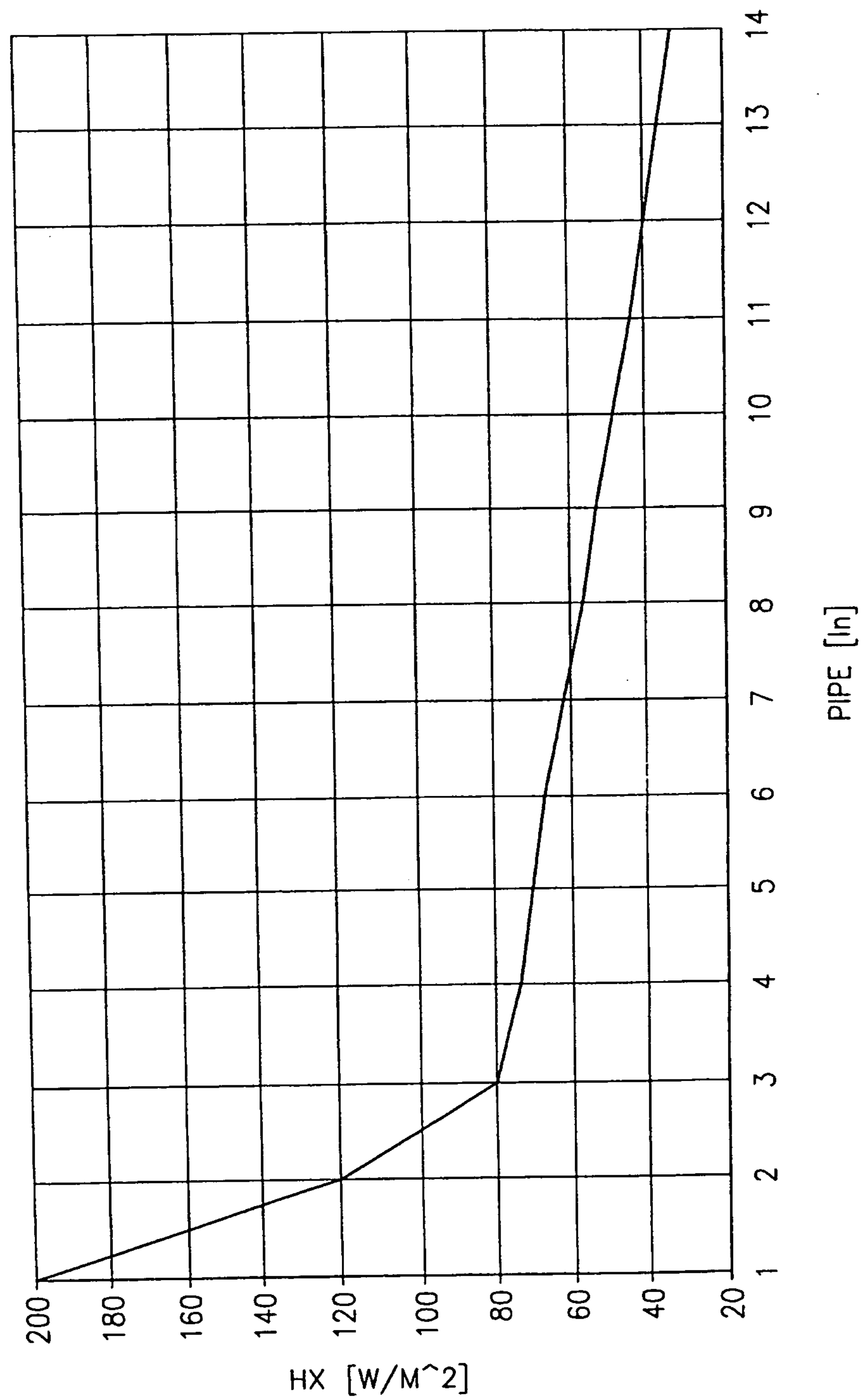
466
481
496
511
526
541
558
571
a
b
c
d
e
f

FIG.5


HX [W/M^2]
200
180
160
140
120
100
80
60
40
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PIPE [In]
1
2
3
4
5
6
7
8
9
10
11
12
13
14

FIG.6

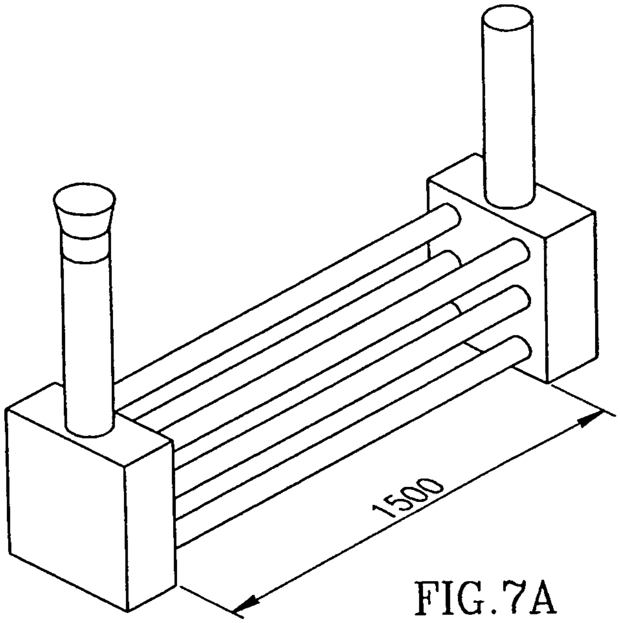


FIG.7A

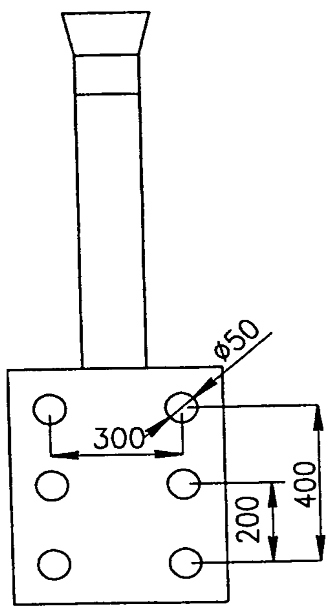
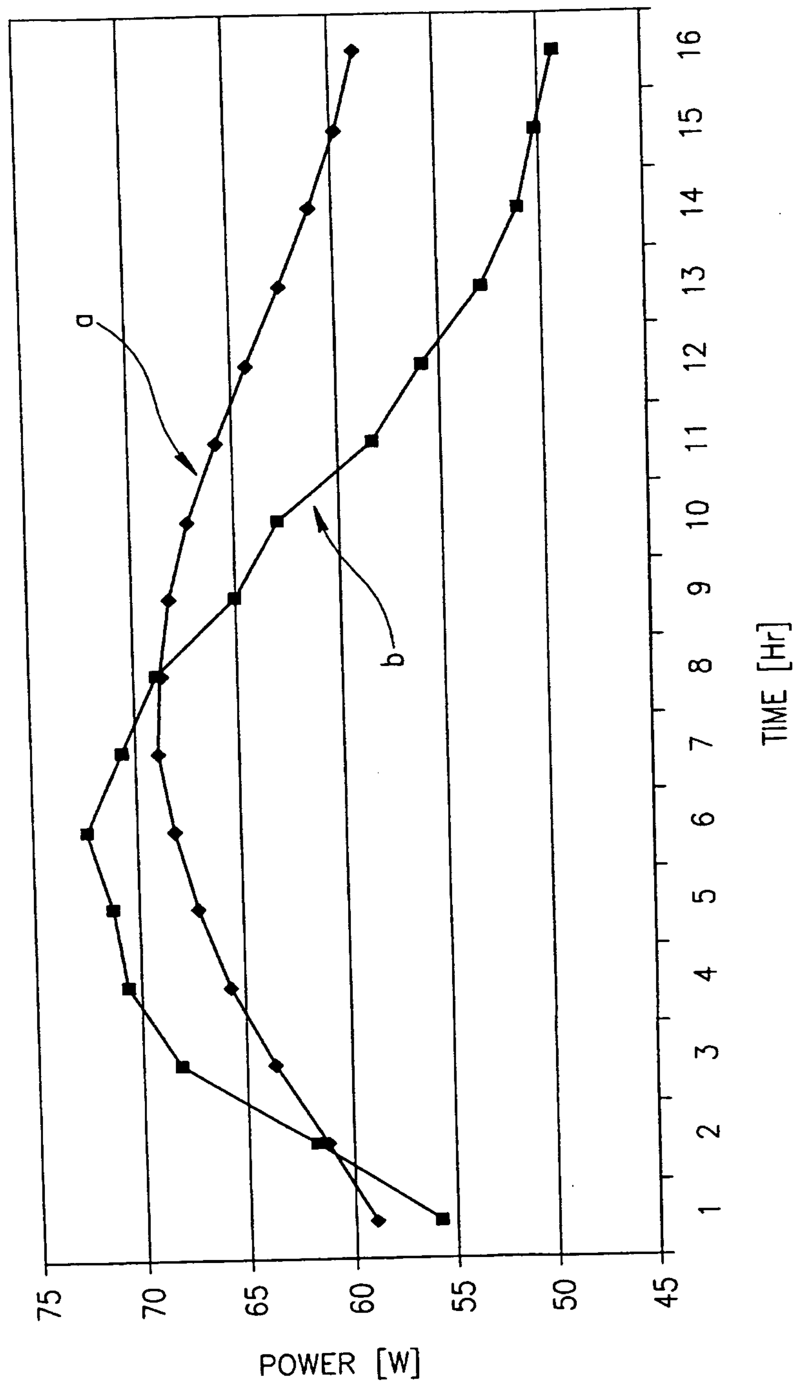


FIG.7B


POWER [W]
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70
65
60
55
50
45
TIME [Hr]
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
a
b

FIG.8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 00/00199

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05K7/20 H02B1/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05K H02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 216 577 A (SCHILLING ROBERT J) 1 June 1993 (1993-06-01) column 1, line 5 -column 1, line 10 column 2, line 49 -column 2, line 58 column 2, line 62 -column 3, line 2 column 4, line 16 -column 4, line 31 column 4, line 61 -column 4, line 64 column 5, line 15 -column 5, line 45 column 6, line 30 -column 6, line 39; figures 1,8 ---	1,4-9, 12,14,16 2,3,10, 13,15
Y	US 4 921 039 A (GHIRALDI ALBERTO) 1 May 1990 (1990-05-01) column 1, line 9 -column 1, line 42 ---	13,15

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 July 2000	03/08/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Schneider, F

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 4 448 238 A (SINGLETON JR LEWIS ET AL) 15 May 1984 (1984-05-15) column 2, line 47 -column 2, line 49 column 3, line 16 -column 3, line 19 column 4, line 4 -column 4, line 7 column 4, line 34 -column 4, line 40 column 7, line 57 -column 7, line 60 figures 1,3,11 ---	2,10 6-9
Y	PATENT ABSTRACTS OF JAPAN vol. 006, no. 256 (M-179), 15 December 1982 (1982-12-15) -& JP 57 150743 A (ADACHI JIMUSHIYO:KK), 17 September 1982 (1982-09-17) abstract; figure 4 ---	3
Y	WO 97 50282 A (REDDICLIFFE EDWARD A) 31 December 1997 (1997-12-31) page 1, line 9 -page 1, line 16 page 1, line 25 -page 1, line 28 page 5, line 9 -page 5, line 19 page 5, line 33 -page 5, line 35; figures 2,5 ---	1,4-6, 12,14,16
Y	PATENT ABSTRACTS OF JAPAN vol. 009, no. 080 (M-370), 10 April 1985 (1985-04-10) -& JP 59 208336 A (KAZUYOSHI OOSHITA), 26 November 1984 (1984-11-26) abstract ---	1,4-6, 12,14,16
A	MUKERJI S.: "steady-state heat transfer analysis of arbitrarily coiled buried pipes" JOURNAL OF THERMOPHYSICS AND HEAT TRANSFER, vol. 11, no. 2, 1997, pages 182-188, XP000925489 cited in the application ---	
A	RABIN Y. KORIN E.: "thermal analysis of a helical heat exchanger for ground thermal storage in arid zones" INTERNATIONAL JOURNAL OF HEAT AND MASS TRANFER, vol. 39, no. 5, March 1997 (1997-03), pages 1051-1065, XP000925497 cited in the application -----	

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/IL 00/00199

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5216577 A	01-06-1993	NONE	
US 4921039 A	01-05-1990	IT 1205101 B JP 1270940 A	15-03-1989 30-10-1989
US 4448238 A	15-05-1984	NONE	
JP 57150743 A	17-09-1982	NONE	
WO 9750282 A	31-12-1997	AT 183875 T DE 69700453 D DE 69700453 T EP 0852898 A ES 2135293 T	15-09-1999 30-09-1999 11-05-2000 15-07-1998 16-10-1999
JP 59208336 A	26-11-1984	JP 1517272 C JP 63067109 B	07-09-1989 23-12-1988